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INTEGRATING TV/DIGITAL DATA SPECTROGRAPH SYSTEM

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16. ABSTRACT A 25-mm SEC vidicon camera was previously modified to allow operation in an integration mode for low-light-level astronomical work. The camera has been mated to a low-dispersion spectrograph for obtaining spectral information in the 400 to 750 nm (4000 to 7500 Å) range. A recently developed high speed Digital Video Image System (DVIS) was utilized to digitize the analog video signal, place the information directly into computer-type memory, and place it onto digital magnetic tape for permanent storage and subsequent analysis.					
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INTEGRATING TV/DIGITAL DATA SPECTROGRAPH SYSTEM

INTRODUCTION

One of the spare Skylab/Apollo Telescope Mount (ATM) low-light-level cameras was modified, as a Summer Faculty Fellow project of Dr. Kent Honeycutt [1], to operate in an integration mode. A specially selected 25-mm SEC vidicon was installed (by Sperry, Inc.) in the camera, which was modified to allow external control of blanking, filament, and high voltage. External TTL logic circuitry was built to provide observer control of initiation and duration of target exposure to scene. The camera, with an S-20 photocathode, was mated to a low-dispersion (Spotz) spectrograph to obtain spectra in the 400 to 750 nm (4000 to 7500 Å) range. Operation in second order allows simultaneous coverage of a 140 nm (1400 Å) band, selectable by grating tilt throughout the 350 nm (3500 Å) range. Spectral resolution obtainable is on the order of 0.6 nm (6 Å). The recently developed Digital Video Image System (DVIS) was used for buffer storage (required because the target information is destroyed during readout scanning) incorporating a high speed analog to digital conversion of the video signal and direct storage into memory of the digitized (6 bit) data. Once in memory, the information is readily available for near-real-time display, inspection, and permanent digital magnetic tape storage of any selected portion at the operator's convenience and discretion. The overall system block diagram is depicted in Figure 1.

EQUIPMENT DESCRIPTION

Camera

At the heart of the system is the target of the SEC vidicon (type WX-30691NC). The camera is shown schematically in Figure 2. The 25-mm diameter vidicon tube is basically a two-section device, with an electrostatically focused diode image section and a magnetically focused and deflected readout section. A plano-convex fiber optic faceplate has an S-20 photocathode

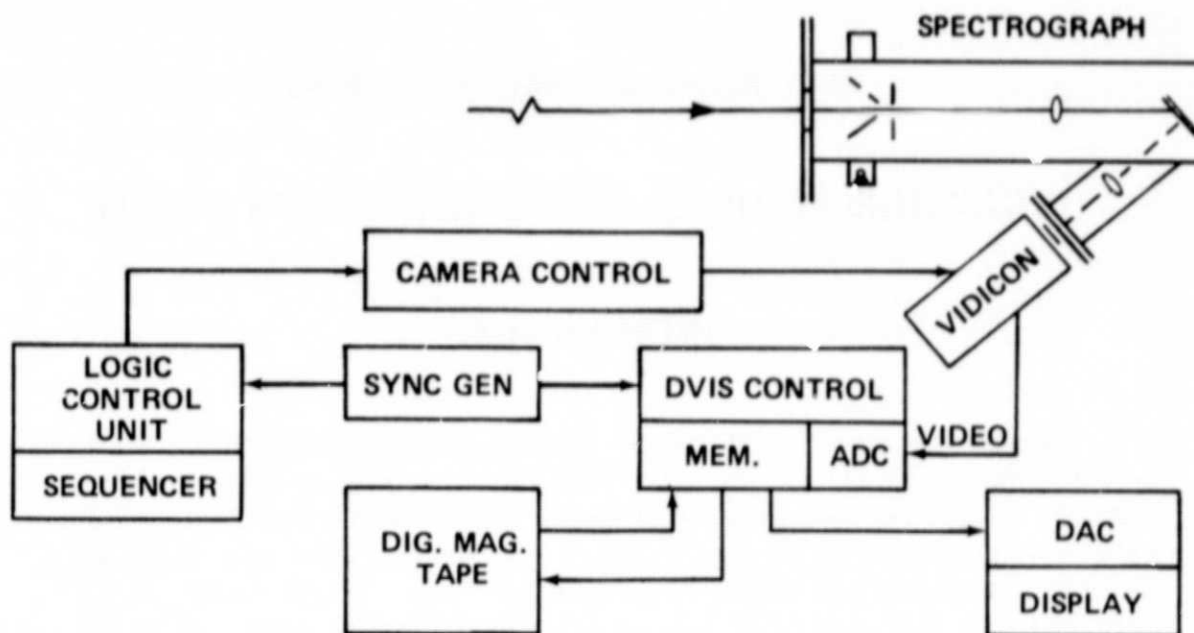


Figure 1. Integrating TV/digital data spectrographic system.

deposited on its inner surface. The optical image incident on the faceplate is transformed into an electron image which is electrostatically focused by the anode onto the target. The photoelectron energy is variable up to 8 keV by control of the accelerating high voltage supply.

The SEC target has an Al_2O_3 supporting membrane, followed by an aluminum signal electrode upon which is deposited a thick, highly porous layer of KCl. The photoelectrons, penetrating the support and signal electrode, dissipate their energy in the KCl by generating secondary electrons. These secondary electrons are trapped in the vacuum voids between the KCl particles. The positive potential applied to the signal electrode establishes an electrical field across the KCl layer (the surface of the KCl being maintained essentially at gun cathode potential by the read beam). The secondary electrons migrate toward the signal electrode, leaving the KCl target surface positively charged with a spatially distributed image whose intensity corresponds to the optical image. The high resistivity of the porous KCl material (the secondary electrons are essentially "trapped" in the vacuum voids) allows very little cross-conduction or leakage and, thus, long storage periods without degradation of intensity or resolution in the stored image. The variations in charge pattern result in a corresponding current variation in the neutralizing "read" beam as it is scanned by the deflection mechanism across the target. The effective capacitance across the target couples this current fluctuation to the signal electrode, and the video analog voltage is developed across a load resistor to ground.

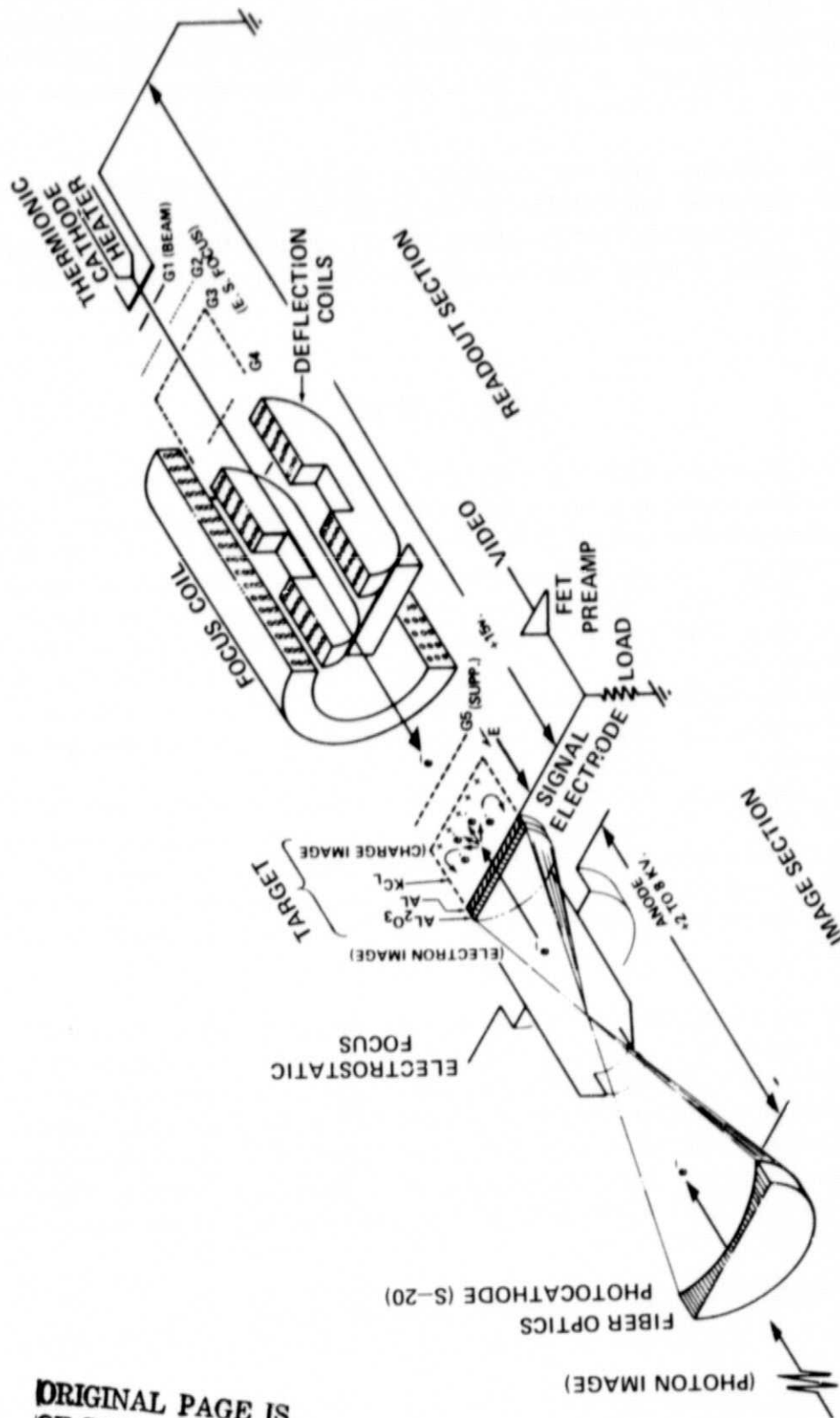


Figure 2. SEC vidicon.

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The video pre-amp is adjacent to the tube target within the camera head, which also contains the deflection, focus, alignment, and blanking mechanisms along with the high voltage supply and filter circuitry. The remaining circuitry, including power supplies, vertical sweep circuits, and video processing, is contained in a separate camera control unit.

A blemish-free tube was selected (at some sacrifice in uniformity of target area response) and installed in one of the low-light-level cameras obtained from the Skylab/ATM program, which, along with its camera control unit, was modified to allow external control of high voltage, filament, and blanking.

Logic Control

The TTL digital logic circuitry was designed and built for timed, sequential camera control to allow integration of low light signals onto the target for a selectable time period [1]. Dr. Honeycutt's reports [1]* contain a complete description of the logic control and sequencer. Briefly, an expose command initiates target preparation, consisting of a selectable number of expose/read cycles wherein the target is flooded with diffuse light and read off to insure uniformity. Then, a number, again selectable, of read-only cycles are performed to reduce the residual charge level on the target. Following target preparation, the filament is turned off and allowed to cool down for a selectable period. A logic signal turns on the high voltage, and integration of the unknown image onto the target is under way (filament voltage remains "off" during integration). The readout beam is blanked during integration and during a selectable warmup period for the filament after integration is terminated by turning off high voltage. A logic signal then unblanks the readout beam and alerts the recording mechanism, and the single frame of video analog information is read out.

Clocking for all the logic signals is derived from standard EIA sync pulses, and readout of the single frame (field) of information is at the commercial video rate of 256 horizontal lines in 1/60 sec. Almost all of the information content of the integrated image is contained in the first field readout, since the readout beam neutralizes the target. Thus, the second field contains little information and is generally not utilized. Effectively, then, a single field of information with 256 vertical lines of 4.5 MHz video data is the analog output obtained from the system.

*Honeycutt, R. K.: Vidicon Sequencer. Informal Report, 1974.

Digital Video Image System

The Digital Video Image System provides an interactive recording and display device. It acts as a very high speed data input/output interface between analog (video) signals and standard digital computer components. It has considerable flexibility of resources (e.g., picture size versus memory size) and can be expanded to operate under computer control to further increase its capabilities. As presently configured, there are four modes of operation:

1. Video display (refresh static frame).
2. Video record (one frame).
3. Make digital tape (transfer contents of memory to bulk storage).
4. Enter digital tape (load memory from bulk storage).

After completion of any of the last three modes, the system reverts to display.

In the video record mode, one frame of NTSC video data can be digitized at video rates and stored in a regular core memory. For display, the digital image stored in core is used to refresh a standard video monitor through repeated readout from memory and reconstruction of a standard (NTSC) composite video signal.

Access to and from the memory is also possible at nonvideo rates. Thus, the digitized image may be read out from the memory and written onto a computer-compatible digital magnetic tape; alternatively, a digitized image contained on magnetic tape may be written into memory. With the digital tape recorder used in the current system, this memory buffer technique provides a data rate reduction of 1000:1. Thus, the 10-MHz video sampling rate is reduced to the 10-kHz rate of the recorder.

A block diagram of the DVIS is shown in Figure 3.

Recording

Digitizing. The bandwidth of the video signal (5 MHz) necessitates sampling and digitizing the incoming signal every 100 ns (10-MHz sample rate). Each sample pixel (i.e., picture element) is coded to 8 bits in a high-speed analog-to-digital converter (ADC). Prior to digitizing, the composite video signal is conditioned for input to the ADC by clamping the reference black level, stripping out the sync signal, and amplifying the video portion of the signal.

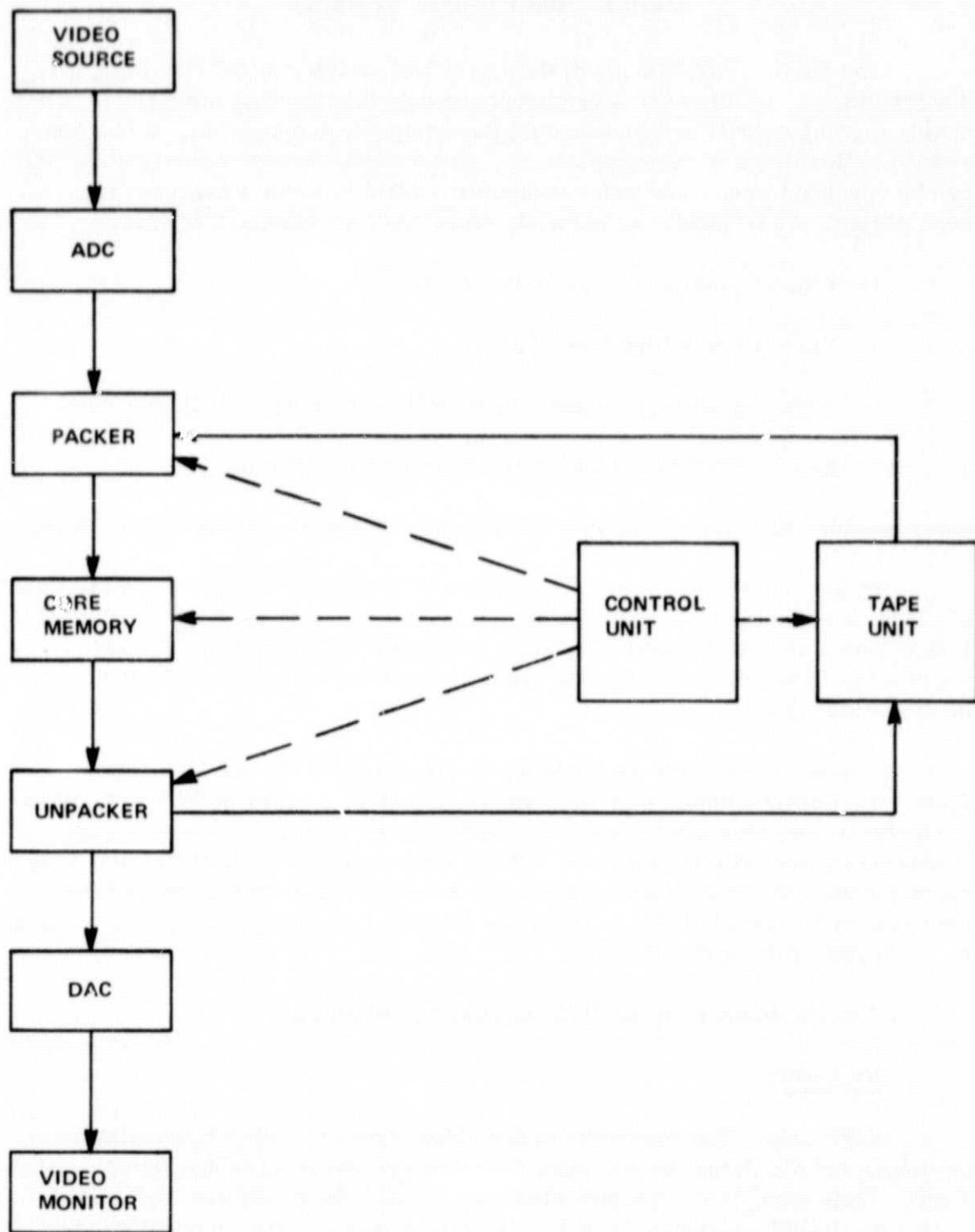


Figure 3. Block diagram Digital Video Image System.

Memory Input. The high data acquisition rate (100 ns per pixel) is matched to the memory cycle time (650 ns) by configuring the memory with a widened word size ($32K \times 64$ -bit words) and packing the data. Eight pixels (of 8 bits each) are packed in an Input Buffer Register, allowing the memory to be cycled every 800 ns. A complete 512×512 video image can be recorded in $1/30$ second.

Digital images stored on magnetic tape can be written into memory through the same Input Buffer Register. In this case, the basic clock cycle is determined by the digital tape recorder and results in the memory being cycled approximately every 800 ns. A 512×512 pixel frame can be entered in approximately 90 seconds (including record gaps).

Image Memory. The maximum image size that can be stored is determined by the amount of core memory provided. In the current system, the memory capacity is $32K \times 64$ -bit words or $256K \times 8$ -bit bytes. This allows storage of a total of 262 144 pixels. If desired, all of these pixels can come from a single full 512×512 frame of video data. However, several pictures which are smaller than full frame can be stored through the use of a picture-size management and memory allocation scheme. There are two sets of thumbwheel switches designated ($X_{\text{BEGIN}}, X_{\text{END}}$) and ($Y_{\text{BEGIN}}, Y_{\text{END}}$) which determine the size of the image to be recorded and where it is to be taken within the video frame. Two other thumbwheel switches ($MEM_{\text{BEGIN}}, MEM_{\text{END}}$) determine the starting and ending addresses within the core memory at which the picture is to be stored. These control features allow compression of the recorded data and simultaneous display of several images for comparison purposes. For example, recalibration of the grating settings is simplified through storage of calibration spectra.

Display

Memory Output. The digitized image data are obtained from memory in a manner which is exactly the reverse of the memory input technique. For each memory cycle, a full 64-bit word is read out of memory and clocked into an Output Buffer Register. For generation of digital video, this memory cycle occurs every 800 ns, and the eight 8-bit pixels are unpacked every 100 ns. For bulk storage, the digital data is written onto magnetic tape through the same unpacking process. As before, the basic clock cycle is determined by the digital tape recorder.

Video Output. Reconstruction of a composite video signal from the 100 ns pixel stream is achieved through data conversion in a high speed digital-to-analog converter (DAC), followed by reinsertion of video synchronization signal and attenuation in a video amplifier.

Display of the stored image is continuous at standard video rates until a new image is recorded or the tape mode of operation is used, either Enter Tape or Make Tape. Upon completion of any of these modes, the system reverts automatically to the display mode and continues to display whatever image is currently in memory.

Operation. Recording of each spectral image is initiated by a logic signal (STORE) received from the Camera Control Unit (CCU). This signal is used to trigger the Record mode within the DVIS, causing the next video frame to be digitized. Synchronization of CCU and DVIS is achieved by feeding both units from the same video sync generator.

Automatic writing of the data onto magnetic tape is provided if required. Receipt of the signal STORE starts a timer which runs for approximately 10 seconds. This interval allows the digitized spectrum to be briefly studied and a decision made as to its suitability for recording on tape. If no action is taken, the timer will trigger the Make Tape mode and the image will be recorded on magnetic tape. If the spectrum is not required for tape storage, the automatic triggering of Make Tape may be inhibited.

Spectrograph

The SEC vidicon camera has been mated to a low-dispersion grating spectrograph manufactured by Boro Spitz (Fig. 4). The instrument is normally mounted at the Cassegrainian focus of the telescope by the circular flange provided. The field view eyepiece is used to observe the celestial body under investigation off the back surface of the reflex mirror or from the reflected image off the instrument's entrance slit-jaws. Immediately behind the adjustable entrance slit is a dark slide/filter mount. The instrument uses an f/13.5 collimator and has a 5.08 cm (2 in.) square grating ruled with 600 grooves per millimeter. The grating blaze is for 500 nm (5000 Å) in second order (also useable in first order). The grating is rotatable via a calibrated micrometer screw. The 10.16-cm (4-in.) focal length camera lens (adjustable) brings the spectrum to focus at a detector mount to which may be attached a photographic plate camera, image tube, or the vidicon. Spectral dispersion is 8 nm (80 Å) per millimeter (second order), with a range of 150 nm (1500 Å) at the focal

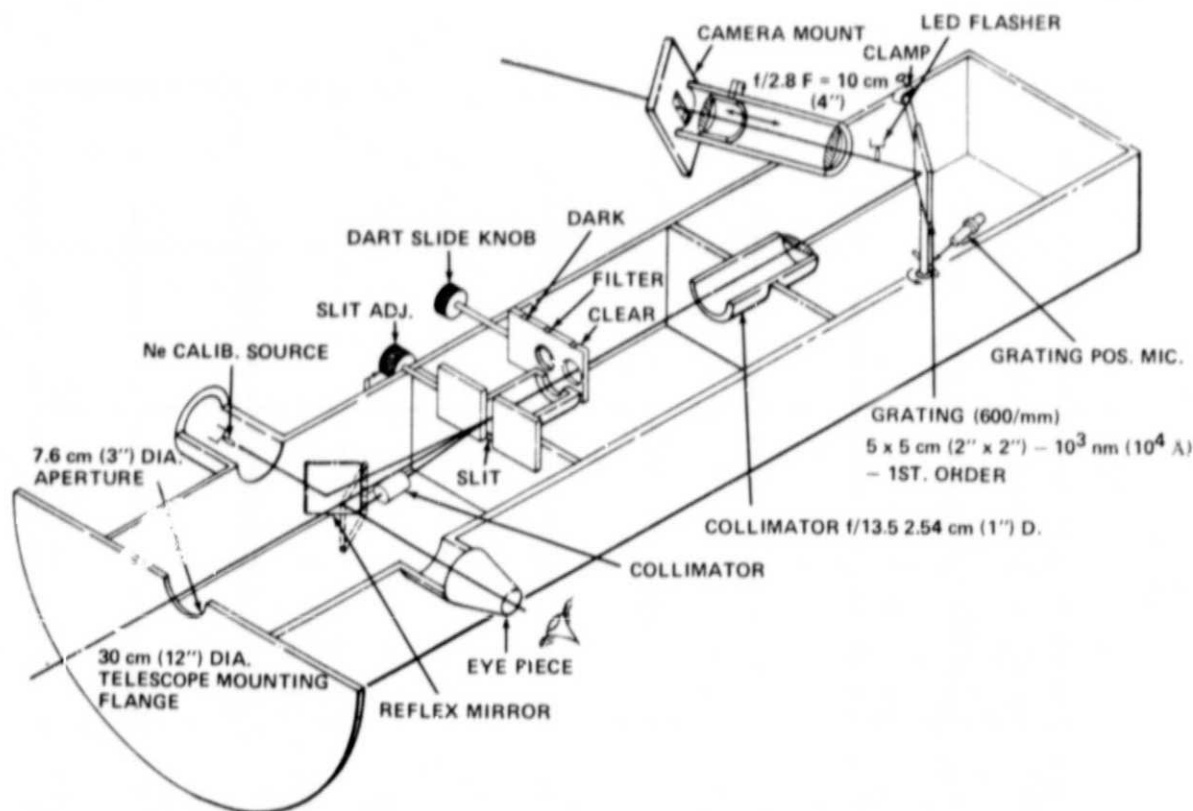


Figure 4. Boro Spatz low dispersion spectrograph.

plane. The instrument has provision for spectral calibration of the detector/spectrographic combination by using the known emission lines of the neon/argon source introduced into the slit by use of the reflex mirror. Figure 5 represents a typical calibration, a horizontal line tracing through a video image field, following exposure to the reference line source.

PERFORMANCE

When mated to the SEC vidicon, the $8 \text{ nm } (80 \text{ Å})/\text{mm}$ spectrographic dispersion (second order) gives a horizontal range of $140 \text{ nm } (1400 \text{ Å})$ in the active $17.5 \text{ mm} \times 17.5 \text{ mm}$ square inscribed in the 25-mm diameter tube face. A 256-line horizontal resolution (camera MTF = 0.5) results in $256/17.5 = 15 \text{ lines/mm}$, or about $80/15 = 0.6 \text{ nm } (6 \text{ Å})$ spectral resolution. On a single field of information 256 vertical TV lines are contained in the 17.5-mm

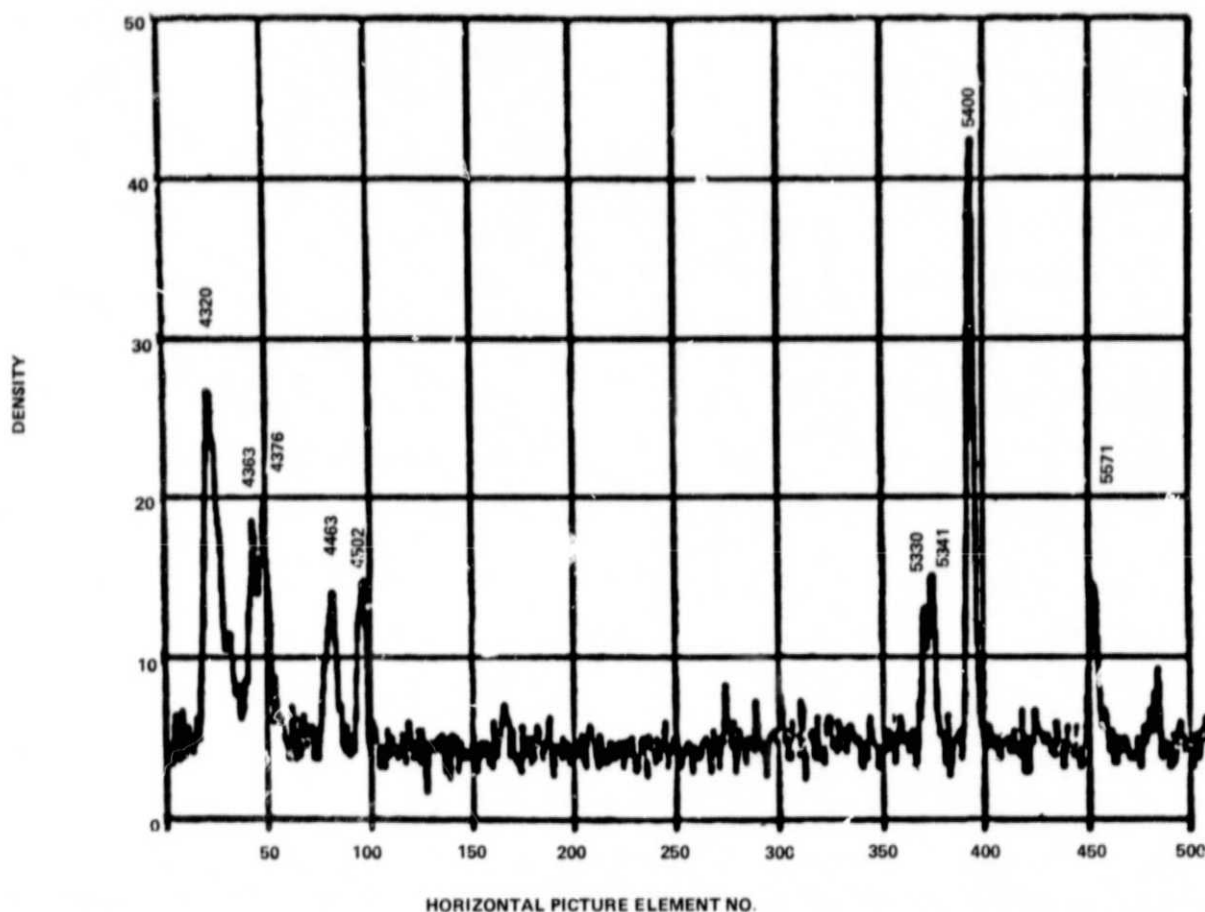


Figure 5. Horizontal line tracing through the blue spectrum.

photocathode or, again, 15 lines/mm. The spectrograph's slit is stopped to about 12.5 mm (0.5 in.), and the focal ratio of the collimator to camera lens is about 3.4. Hence, only $12.5/3.4$ (15 lines)/mm = 57 lines of the photocathode can be illuminated by the slit.

The camera MTF of 0.5 at 256-line resolution degrades to 0.1 at 512 lines. Figures 5 and 6 are traces through the blue and red spectra, respectively, obtained from the reconstructed digital images of the spectrograph's neon/argon wavelength calibration source.

Photometric calibration of the vidicon has yet to be accomplished on a complete, pixel-by-pixel basis. Figure 7 is the result of varying exposure time of the target to the spectrograph's neon/argon calibration source. This,

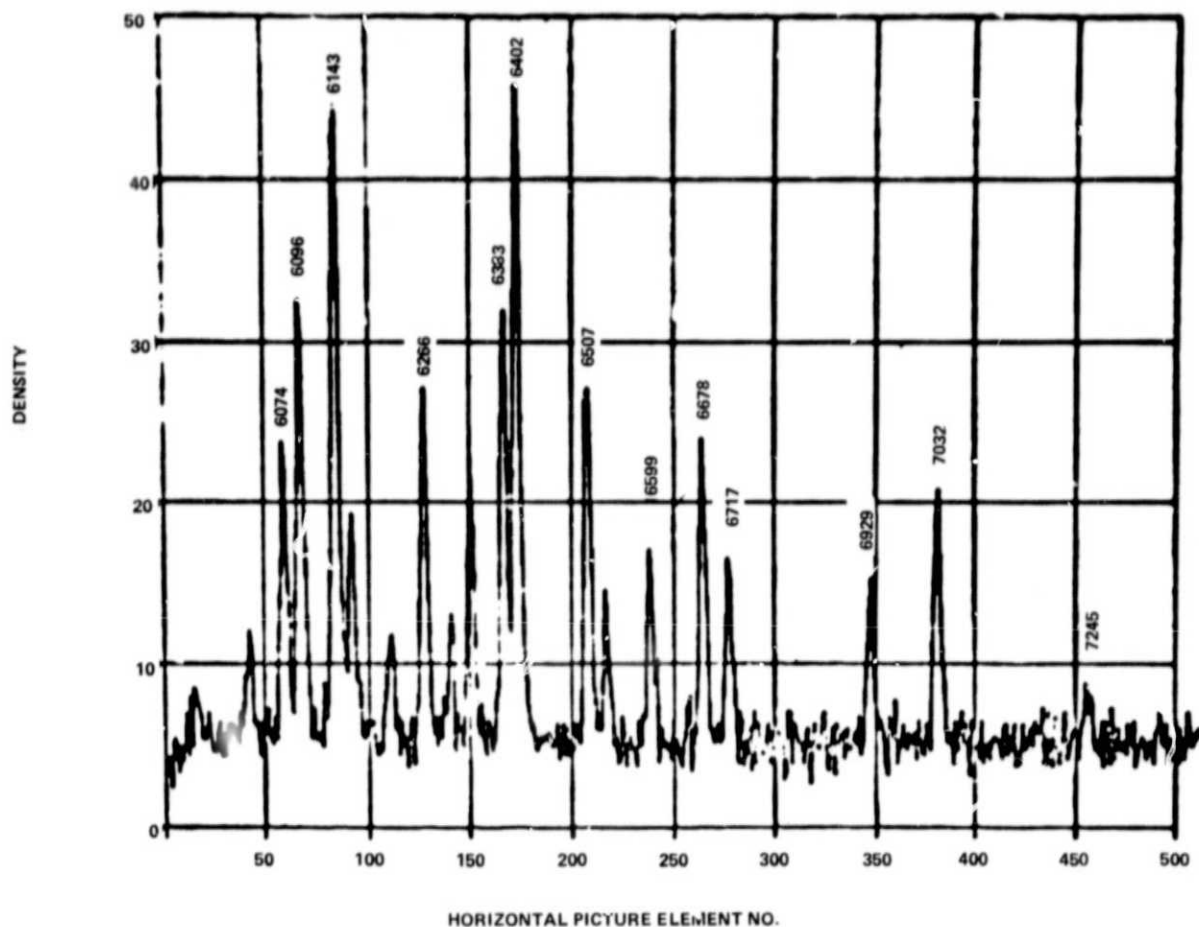


Figure 6. Horizontal line tracing through the red spectrum.

assuming that the integrated flux for a given emission line over a given integral of time is constant, provides an output-versus-light flux at selected target positions. This has been checked (within 5 to 10 percent) by use of neutral density filters to vary light intensity by a known amount. This calibration is more fully discussed in Reference 2. A uniform, collimated light source (Optoliner) was utilized to check field uniformity, which is in the 5 to 10 percent range except at the extreme edges of the photocathode where a drop of about 20 percent is experienced.

Dark current in the SEC is negligible; hence, the prime consideration in the analog signal is the Johnson noise in the video circuitry, plus background. For this, the equivalent preamp input noise gives an S/N ratio of 26 dB (for a 100-nanoamp signal). Analog error in the A/D converter is only 0.2

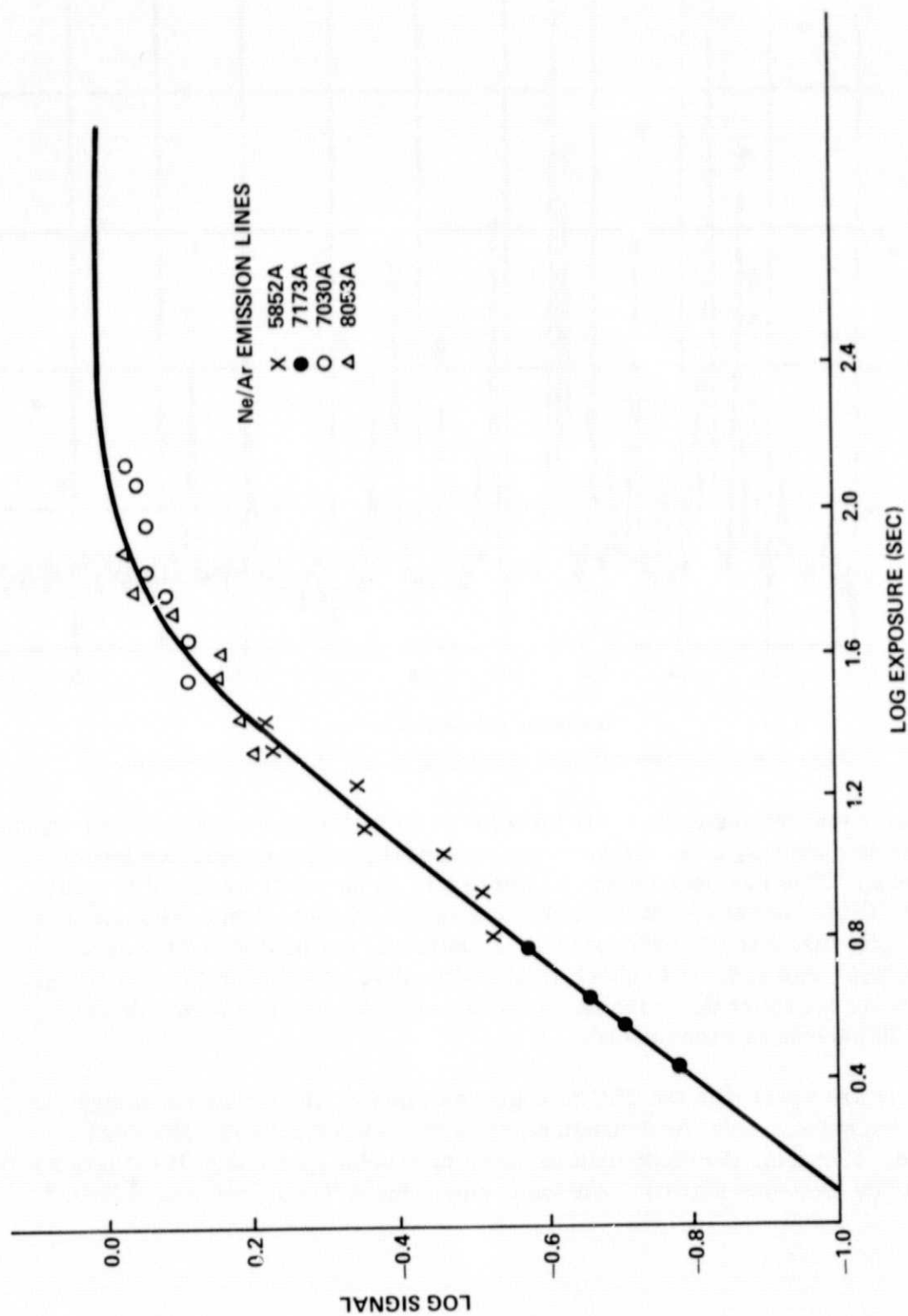


Figure 7. Intensity versus exposure.

percent of full scale, and the digital quantization error (one significant bit) and aperture error of sampling (± 30 picosec at 100-ns sample rate) are less than one bit (one part in 256). Hence, overall we should have a per pixel S/N maximum of 20/1 (preamp limited). In practice, including background, we have attained about one-half as good as this on an individual pixel basis. Figures 5 and 6 are five line averages through reconstructed images of the calibration spectra. Figure 8 is a typical planetary spectrum (of Saturn). It can be seen that the noise levels are about 2.5 gray scales (out of 64); thus, the per pixel noise, $\sqrt{5}$ (2.5), is about 6, giving an S/N of 10. For spectra of point sources, the entire 50 video lines across the spectra may be averaged at a given wavelength, with resultant S/N improvement to 70 ($10\sqrt{50}$) by trailing along the slit. For extended sources, a trade-off can be made between S/N and spatial resolution along the slit.

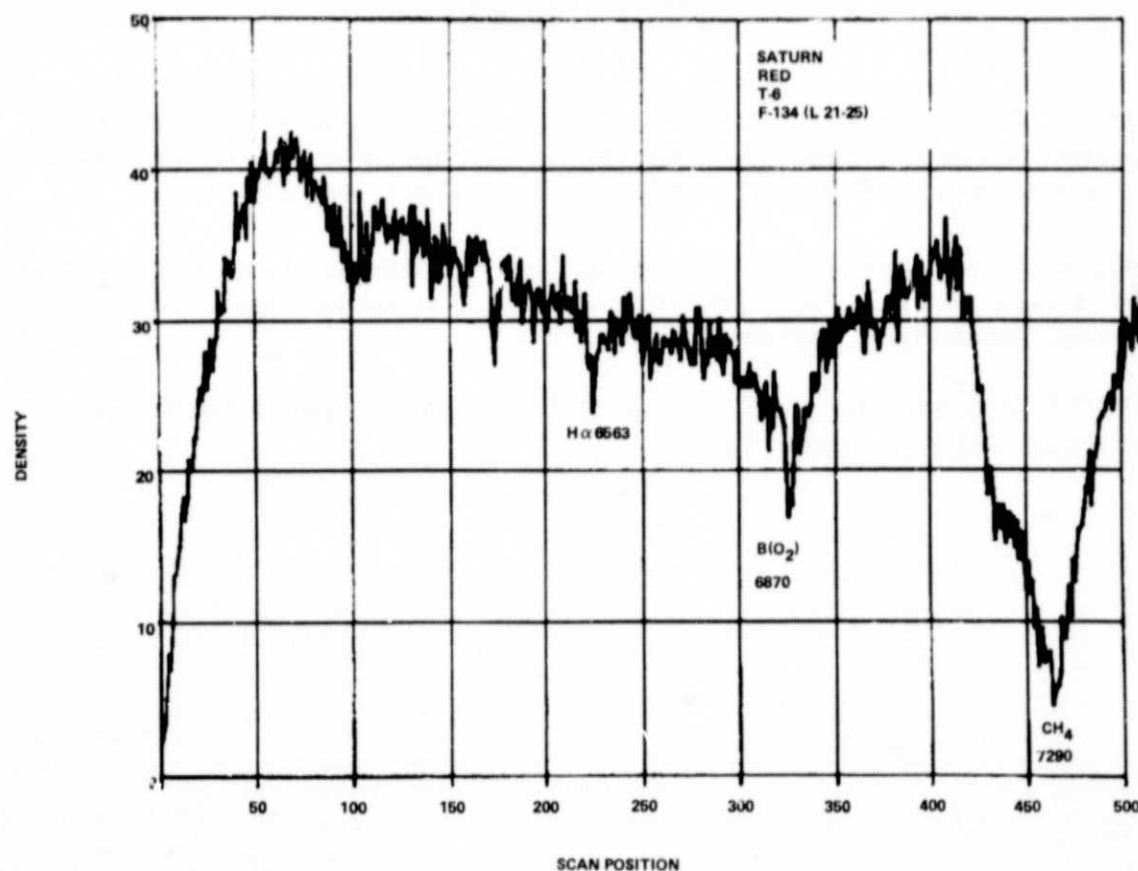


Figure 8. Typical planetary spectrum.

REFERENCES

1. Honeycutt, R. N.: A Video Data Acquisition System for Ground-Based Astronomy. ASEE-NASA Summer Faculty Fellowship Program Report, 1973.
2. Fay, T. D.: Calibration and Reduction of Video Camera Data. ASEE-NASA Summer Faculty Fellowship Program Report, 1974.

BIBLIOGRAPHY

Duncan, B.; Wamsteker, W.; and Fay, T. D.: Digital Video System for Rapid Spectral and Spatial Mapping of Planets. Paper Presented at 145th Meeting of American Astronomical Society, Bloomington, Indiana, March 1975.

Fay, T. D. and Duncan, B.: Spatial and Spectral Mapping of Jupiter and Saturn with a T.V. System. Paper presented at 145th Meeting American Astronomical Society, Bloomington, Indiana, March 1975.

MSFC Specification 50 M12775 — Low Light Level Television Camera System for Apollo Telescope Mount Project.

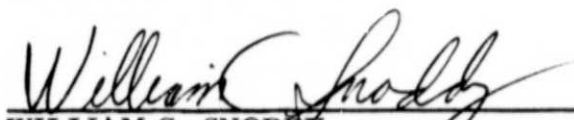
APPROVAL


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This document has also been reviewed and approved for technical accuracy.


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